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NIXON & VANDERHYE, PC
1100 N GLEBE ROAD
8TH FLOOR
ARLINGTON, VA 22201-4714

EXAMINER	
MUTSCHLER, BRIAN L	
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Please find below and/or attached an Office communication concerning this application or proceeding.

C?/(C

Office Action Summary	Application No.	Applicant(s)
	09/955,297	ROHR ET AL.
	Examiner	Art Unit
	Brian L. Mutschler	1753

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *26 November 2003*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-18,20-27,31-33 and 35-58* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-18,20-27,31-33 and 35-58* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. §§ 119 and 120

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

13)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application) since a specific reference was included in the first sentence of the specification or in an Application Data Sheet. 37 CFR 1.78.

a) ☐ The translation of the foreign language provisional application has been received.

14)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121 since a specific reference was included in the first sentence of the specification or in an Application Data Sheet. 37 CFR 1.78.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☐ Information Disclosure Statement(s) (PTO-1449) Paper No(s) _____ .

4) ☐ Interview Summary (PTO-413) Paper No(s). _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: .

DETAILED ACTION

Comments

1. Applicant's cancellation of claims 19 and 34 in the amendment submitted November 26, 2003, is acknowledged.

2. Applicant's incorporation of the subject matter of claims 19 and 34 into claims 18 and 33, respectively, has overcome the rejections of claims 18 and 33 set forth in the prior Office action. In response, the rejections of claims 18 and 33, and their dependent claims, have been modified accordingly. (It is noted that the rejections of claims 31-33 and 35-41 have been presented in separate sections; the rejections are based on the same combination of references using the same rejection set forth previously, but since they pertain to two groups of independent claims, claims 18 and 33, presenting the claims in separate sections helps prevent confusion between the two groups of claims.)

Claim Rejections - 35 USC § 102

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

4. Claims 1-6, 12, 13, 42 and 43 are rejected under 35 U.S.C. 102(b) as being clearly anticipated by Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters).

Ekins-Daukes et al. disclose a solar cell having strain-balanced quantum wells, wherein the quantum wells contain alternating compressively strained InGaAs quantum wells and tensile strained GaAsP barriers, and "the dimensions were chosen to ensure the average lattice parameter across the *i* region <*a*> was equal to that of [the GaAs substrate]", i.e., the strain over each period is zero (p. 4195). Specifically, Ekins-Daukes et al. teach, "The *i* region was designed as a 20 period cyclic half-barrier/QW/half-barrier structure; each half barrier composed of GaAsP alloy, providing half the strain compensation for the InGaAs QW" (see page 4195). Since the strain is zero over each period, each period exhibits zero shear force on neighboring structures, which includes a further period or the substrate. Ekins-Daukes et al. disclose that the average strain is a "negligible quantity" (p. 4195).

Regarding claim 3, the recitation of the lattice constant of the substrate and the quantum wells inherently describes a crystalline device. A lattice constant is a measure of the distance between adjacent atoms in a regularly spaced arrangement, or crystal structure.

Regarding claims 4 and 5, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claim 6, a period of one quantum well and one barrier layer contains four elements: In, Ga, As and P.

Regarding claims 12 and 13, Ekins-Daukes et al. disclose the use of a GaAs substrate and InGaAs quantum well layers.

Regarding claims 42 and 43, the quantum wells are compressive strained and the barrier layers are tensile strained (see col. 1 on p. 4195).

Since Ekins-Daukes et al. clearly teach the limitations recited in the instant claims, the reference is deemed to be anticipatory.

Claim Rejections - 35 USC § 103

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 7-11, 14 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters) in view of Freundlich et al. (U.S. Pat. No. 5,851,310).

Ekins-Daukes et al. disclose a solar cell having the limitations recited in claims 1-6, 12, 13, 42 and 43 of the instant invention, as explained above in section 7.

The device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose the following:

a. The substrate is InP and the compressively strained layer is $In_xGa_{1-x}As$, where x>0.53, as recited in claim 7;

b. The substrate is InP and the tensile strained layer is $In_xGa_{1-x}As_{1-y}P_y$, where y>1, as recited in claim 8;

c. The tensile layer is GaInP, as recited in claim 9;

d. The substrate is InP and the quantum well is formed of layers of $Al_xGa_{1-x}As_ySb_{1-y}$, as recited in claim 10;

e. The substrate is GaSb and the quantum well is formed of layers of $In_xGa_{1-x}As_ySb_{1-y}$, as recited in claim 11;

f. The quantum well portion is formed on a virtual substrate having a virtual substrate lattice constant different from the lattice constant of the substrate, as recited in claim 14; and

g. The virtual substrate is $InP_{1-y}As_y$, where $0<y<1$, and the substrate is InP, as recited in claim 15.

Regarding claims 7-10 and 15, Freundlich et al. disclose a solar cell having an MQW with an InP substrate (fig. 1). The solar cells use InP because it has a high efficiency (col. 2, lines 30-41).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use an InP substrate as taught by Freundlich et al. because InP cells have a high efficiency.

Regarding claims 7-11, Freundlich et al. disclose that materials usable for fabricating the solar cells include InGaAs and "all alloys of indium gallium arsenide with the addition of iso-valent elements such as phosphorous, aluminum, and antimony in concentrations such that the lattice mismatch is less than 0.3 per cent compared to $In_{0.53}Ga_{0.47}As$" (col. 5, lines 26-39). Freundlich et al. further disclose a specific example using $In_xGa_{1-x}As$, where $0.48<x<0.55$ (col. 5, line 52).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use materials having the compositions taught by Freundlich et al. because Freundlich et al. teach that "these alloys have somewhat different energy bandgaps, which may be desirable in some applications" (col. 5, lines 32-33).

Regarding claim 11, Freundlich et al. disclose that "indium phosphide or other suitable materials well-known in the art may be used as a substrate" (col. 3, lines 58-59).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use other materials to form the substrate as taught by Freundlich et al. because different substrates can provide different desired properties.

Regarding claim 14, Freundlich et al. disclose the use of buffer layers (virtual substrates) "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" (col. 3, lines 58-62).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use a virtual substrate as taught by Freundlich et al. because a virtual substrate helps "accommodate crystal lattice-matching requirements" between the different layers (col. 3, lines 58-62).

Regarding claim 15, Freundlich et al. disclose the use of alloys contained within the indium gallium arsenide series including phosphorous-containing alloys such as InAsP (col. 5, lines 26-39). The buffer layers are chosen to "accommodate crystal lattice-matching requirements" (col. 3, lines 58-62).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should "accommodate crystal lattice-matching requirements", which would be accomplished by the choice of materials with similar properties.

7. Claims 16 and 17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL

SOLAR CELLS", Applied Physics Letters) in view of Freundlich et al. (U.S. Pat. No. 6,150,604).

Ekins-Daukes et al. disclose a solar cell having the limitations recited in claims 1-6, 12, 13, 42 and 43 of the instant invention, as explained above in section 4.

The device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose that the device is a thermophotovoltaic device and that the quantum wells have a bandgap equal to or less than 0.73 eV.

Freundlich et al. disclose a MQW thermophotovoltaic solar cell having a bandgap of 0.49-0.74 eV (Table III). The narrow bandgap quantum wells "allows for more efficient conversion of the IR emission emanating from a black body or selective emitter over a wider range of wavelengths than a conventional single junction cell and decreases transparency losses of the conventional cell" (col. 2, lines 40-45).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use narrow bandgap quantum wells as taught by Freundlich et al. because narrow bandgap quantum wells "allows for more efficient conversion of the IR emission" (col. 2, lines 40-45).

8. Claims 18 and 20-27 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310) in view of Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters).

Regarding claim 18, Freundlich et al. disclose the use of buffer layers (virtual substrates) "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" in MQW solar cells (col. 3, lines 58-62). Freundlich et al. also disclose the use of alloys contained within the indium gallium arsenide series, including phosphorous, aluminum and antimony alloys (col. 5, lines 26-39). The photovoltaic cell is formed on an InP substrate (fig. 1). Freundlich et al. further disclose that the alternating layers in the quantum well portion "are alternately in tensile and compressive strain...[to] reduce the overall strain magnitude in the heterostructure" (col. 7, lines 47-52). Freundlich et al. further disclose that the alternating layers in the quantum well portion "are alternately in tensile and compressive strain...[to] reduce the overall strain magnitude in the heterostructure" (col. 7, lines 47-52).

Regarding claims 21 and 22, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claims 23, 25 and 26, the solar cell is formed on an InP substrate and the quantum well portion comprises four elements: In, Ga, As and P (col. 5, lines 28-32). The lattice constant of each period is the same as the adjacent periods (see Table I). In the embodiment comprising an InAsP/InGaP quantum well system, the InGaP is the tensile strained layer (col. 7, lines 54-55).

Regarding claim 27, Freundlich et al. also disclose the use of GaAsSb in the formation of the solar cell (col. 5, lines 26-39).

The device of Freundlich et al. differs from the instant invention because Freundlich et al. do not disclose the following:

a. An InAsP virtual substrate, as recited in claim 18.

b. A period comprising a quantum well layer and a barrier layer exerts no shear stress on a neighboring structure, as recited in claim 18.

c. The neighboring structure is a further period, a layer of arbitrary doping, or the virtual substrate, as recited in claim 20.

d. The compressively strained layer is InGaAs having a larger percentage of indium than the InGaAs composition having the same lattice constant as the virtual substrate, as recited in claim 24.

Regarding the use of an InAsP virtual substrate as recited in claim 18, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should "accommodate crystal lattice-matching requirements", which would be accomplished by the choice of materials with similar properties.

Regarding claims 18 and 20, Ekins-Daukes et al. teach strain-balancing the quantum well layers and the barrier layers in the solar cells so that no strain exists

between the layers (p. 4195). This approach allows more quantum wells to be incorporated in the solar cell without causing strain relaxation (p. 4195).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to strain-balance the quantum well portion as taught by Ekins-Daukes et al. because balancing the strain within the quantum well portion allows more quantum wells to be used, thus increasing the efficiency of the solar cell.

Regarding claim 24, Ekins-Daukes et al. disclose the use of compressively strained InGaAs layers (p. 4195). Since the layer is compressively strained, the lattice constant is greater than the other layers including the virtual substrate. A layer of InGaAs with a lattice constant the same as the virtual substrate would have a lower concentration of indium.

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to use compressively strained InGaAs layers as taught by Ekins-Daukes et al. because InGaAs quantum wells have been shown by Ekins-Daukes et al. to increase the conversion efficiency of conventional solar cells.

9. Claims 31 and 32 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310) in view of Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied

Physics Letters), as applied to claims 18 and 20-27, and further in view of Freundlich et al. (U.S. Pat. No. 6,150,604).

In US '310, Freundlich et al. and Ekins-Daukes et al. describe a solar cell having the limitations recited in claims 18 and 20-27 of the instant invention, as explained above in section 8.

The device described by Freundlich et al. (US '310) and Ekins-Daukes et al. differs from the instant invention because they do not disclose the following:

a. The device is a thermophotovoltaic device, as recited in claim 31.

b. The quantum wells have a bandgap of 0.73 eV or less, as recited in claims 32.

Regarding claims 31 and 32, Freundlich et al. (US '604) disclose a MQW thermophotovoltaic solar cell having a bandgap of 0.49-0.74 eV (Table III). The narrow bandgap quantum wells "allows for more efficient conversion of the IR emission emanating from a black body or selective emitter over a wider range of wavelengths than a conventional single junction cell and decreases transparency losses of the conventional cell" (col. 2, lines 40-45).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device described by Freundlich et al. (US '310) and Ekins-Daukes et al. to use narrow bandgap quantum wells as taught by Freundlich et al. (US '604) because narrow bandgap quantum wells "allows for more efficient conversion of the IR emission" (col. 2, lines 40-45).

10. Claims 33 and 35-41 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310) in view of Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters) and in view of Freundlich et al. (U.S. Pat. No. 6,150,604).

Regarding claim 33, Freundlich et al. (US '310) disclose the use of alloys contained within the indium gallium arsenide series, including phosphorous, aluminum and antimony alloys (col. 5, lines 26-39). The photovoltaic cell is formed on an InP substrate (fig. 1). In one embodiment, Freundlich et al. disclose an InAsP/InGaP quantum well system, the InGaP is the tensile strained layer (col. 7, lines 54-55). Freundlich et al. also disclose the use of $In_xGa_{1-x}As$ where x can be larger than 0.53 (col. 5, lines 52-54).

Regarding claim 38, Freundlich et al. disclose the use of buffer layers (virtual substrates) "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" in MQW solar cells (col. 3, lines 58-62).

The device of Freundlich et al. (US '310) differs from the instant invention because Freundlich et al. do not disclose the following:

a. The quantum well is comprised of alternating layers of $In_xGa_{1-x}As$, where $x>0.53$, and barrier layers of $Ga_yIn_{1-y}P$, where $y>0$, as recited in claim 33

b. A period of one tensile strained layer and one compressively strained layer exerts no shear force on a neighboring structure, as recited in claim 33.

c. The neighboring structure is a further period, a layer of arbitrary doping, or a substrate, as recited in claim 35.

d. The device is a thermophotovoltaic device, as recited in claim 40.

e. The quantum wells have a bandgap of 0.73 eV or less, as recited in claim 41.

f. The virtual substrate is InPAs, as recited in claim 39.

Regarding claim 33, Freundlich et al. (US '604) disclose the use of InGaAs wells under compressive strain, with a specific example of wells comprising $In_{0.9}Ga_{0.1}As$ (col. 5, line 9).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. (US '310) to use a compressively strained InGaAs layer having a high indium concentration as taught by Freundlich et al. (US '604) because an InGaAs layer with a high indium concentration has a narrower bandgap, which increases the absorption of the IR regions.

Regarding claims 33 and 35, Ekins-Daukes et al. teach strain-balancing the quantum well layers and the barrier layers in the solar cells so that no strain exists between the layers (p. 4195). This approach allows more quantum wells to be incorporated in the solar cell without causing strain relaxation (p. 4195).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to strain-balance the quantum well portion as taught by Ekins-Daukes et al. because balancing the strain

within the quantum well portion allows more quantum wells to be used, thus increasing the efficiency of the solar cell.

Regarding claim 39, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should "accommodate crystal lattice-matching requirements", which would be accomplished by the choice of materials with similar properties.

Regarding claims 40 and 41, Freundlich et al. (US '604) disclose a MQW thermophotovoltaic solar cell having a bandgap of 0.49-0.74 eV (Table III). The narrow bandgap quantum wells "allows for more efficient conversion of the IR emission emanating from a black body or selective emitter over a wider range of wavelengths than a conventional single junction cell and decreases transparency losses of the conventional cell" (col. 2, lines 40-45).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. (US '310) to use narrow bandgap quantum wells as taught by Freundlich et al. (US '604) because narrow bandgap quantum wells "allows for more efficient conversion of the IR emission" (col. 2, lines 40-45).

11. Claims 44-47, 53 and 54 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters).

Ekins-Daukes et al. disclose a solar cell having strain-balanced quantum wells, wherein the quantum wells contain alternating compressively strained InGaAs quantum wells and tensile strained GaAsP barriers, and "the dimensions were chosen to ensure the average lattice parameter across the *i* region <*a*> was equal to that of [the GaAs substrate]", i.e., the strain over each period is zero (p. 4195). Specifically, Ekins-Daukes et al. teach, "The *i* region was designed as a 20 period cyclic half-barrier/QW/half-barrier structure; each half barrier composed of GaAsP alloy, providing half the strain compensation for the InGaAs QW" (see page 4195). Since the strain is zero over each period, each period exhibits zero shear force on neighboring structures, which includes a further period or the substrate. Ekins-Daukes et al. disclose that the average strain is a "negligible quantity" (p. 4195). The strain across one period is a function of the thickness and the material properties of each layer (p. 4195).

Regarding claims 45 and 46, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claim 47, a period of one quantum well and one barrier layer contains four elements: In, Ga, As and P.

Regarding claims 53 and 54, Ekins-Daukes et al. disclose the use of a GaAs substrate and InGaAs quantum well layers.

The photovoltaic device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose equations recited in the claims, especially in regard to the elastic stiffness coefficient, as recited in claim 44.

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have made the photovoltaic device substantially meeting the conditions defined by the equations recited in the instant claims because one of ordinary skill in the art would have recognized that the elastic stiffness coefficient influences the strain within the layers and therefore would have been encompassed by the teachings of Ekins-Daukes et al., who clearly desire that each barrier compensates for the strain of the adjacent quantum well. The person of ordinary skill in the art, who is "a highly skilled and experienced individual" (see page 23 of Applicant's response), would recognize the relationship between the different material properties, such as lattice constant and elastic stiffness coefficient, and their influences on the strain between adjacent layers. As can be seen in the equations recited in the claims and the teachings of Ekins-Daukes et al., the final result is the same; each barrier provides the strain compensation of the adjacent quantum well.

12. Claims 48-52, 55 and 56 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters), as applied above to claims 44-47, 53 and 54, in view of Freundlich et al. (U.S. Pat. No. 5,851,310).

Ekins-Daukes et al. teach the limitations recited in claims 44-47, 53 and 54 of the instant invention, as explained above in section 11.

The device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose the following:

a. The substrate is InP and the compressively strained layer is $In_xGa_{1-x}As$, where x>0.53, as recited in claim 48;

b. The substrate is InP and the tensile strained layer is $In_xGa_{1-x}As_{1-y}P_y$, where y>1, as recited in claim 49;

c. The tensile layer is GaInP, as recited in claim 50;

d. The substrate is InP and the quantum well is formed of layers of $Al_xGa_{1-x}As_ySb_{1-y}$, as recited in claim 51;

e. The substrate is GaSb and the quantum well is formed of layers of $In_xGa_{1-x}As_ySb_{1-y}$, as recited in claim 52;

f. The quantum well portion is formed on a virtual substrate having a virtual substrate lattice constant different from the lattice constant of the substrate, as recited in claim 55; and

g. The virtual substrate is $InP_{1-y}As_y$, where 0<y<1, and the substrate is InP, as recited in claim 56.

Regarding claims 48-51 and 56, Freundlich et al. disclose a solar cell having an MQW with an InP substrate (fig. 1). The solar cells use InP because it has a high efficiency (col. 2, lines 30-41).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use an InP substrate as taught by Freundlich et al. because InP cells have a high efficiency.

Regarding claims 48-52, Freundlich et al. disclose that materials usable for fabricating the solar cells include InGaAs and "all alloys of indium gallium arsenide with the addition of iso-valent elements such as phosphorous, aluminum, and antimony in concentrations such that the lattice mismatch is less than 0.3 per cent compared to $In_{0.53}Ga_{0.47}As$" (col. 5, lines 26-39). Freundlich et al. further disclose a specific example using $In_xGa_{1-x}As$, where $0.48<x<0.55$ (col. 5, line 52).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use materials having the compositions taught by Freundlich et al. because Freundlich et al. teach that "these alloys have somewhat different energy bandgaps, which may be desirable in some applications" (col. 5, lines 32-33).

Regarding claim 48, Freundlich et al. disclose that "indium phosphide or other suitable materials well-known in the art may be used as a substrate" (col. 3, lines 58-59).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use other materials to form the substrate as taught by Freundlich et al. because different substrates can provide different desired properties.

Regarding claim 55, Freundlich et al. disclose the use of buffer layers (virtual substrates) "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" (col. 3, lines 58-62).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use a virtual substrate as taught by Freundlich et al. because a virtual substrate helps "accommodate crystal lattice-matching requirements" between the different layers (col. 3, lines 58-62).

Regarding claim 56, Freundlich et al. disclose the use of alloys contained within the indium gallium arsenide series including phosphorous-containing alloys such as InAsP (col. 5, lines 26-39). The buffer layers are chosen to "accommodate crystal lattice-matching requirements" (col. 3, lines 58-62).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should

"accommodate crystal lattice-matching requirements", which would be accomplished by the choice of materials with similar properties.

13. Claims 57 and 58 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters), as applied above to claims 44-47, 53 and 54, in view of Freundlich et al. (U.S. Pat. No. 6,150,604).

Ekins-Daukes et al. teach the limitations recited in claims 44-47, 53 and 54 of the instant invention, as explained above in section 11.

The device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose that the device is a thermophotovoltaic device and that the quantum wells have a bandgap equal to or less than 0.73 eV.

Freundlich et al. disclose a MQW thermophotovoltaic solar cell having a bandgap of 0.49-0.74 eV (Table III). The narrow bandgap quantum wells "allows for more efficient conversion of the IR emission emanating from a black body or selective emitter over a wider range of wavelengths than a conventional single junction cell and decreases transparency losses of the conventional cell" (col. 2, lines 40-45).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use narrow bandgap quantum wells as taught by Freundlich et al. because narrow bandgap quantum wells "allows for more efficient conversion of the IR emission" (col. 2, lines 40-45).

Response to Arguments

14. Applicant's arguments filed November 26, 2003, have been fully considered but they are not persuasive.

15. Regarding the rejection of the claims, Applicant has restated several arguments presented in the previous response filed July 22, 2003. Applicant argues, "Ekins-Daukes I teaches the desirability of having 'compositions such that a period of one tensile strained layer and one compressively strained layer exerts substantially no shear force on a neighboring structure' but does not teach a method of achieving this desired result" (see page 15 of Applicant's response). Furthermore, Applicant argues, " [A]s certified by Dr. Anderson's Declaration at paragraphs 10 and 11, those of ordinary skill in the art reading the Ekins-Daukes I reference are not provided with any method for creating layers in which each individual period exerts 'substantially no shear force on a neighboring structure'" (see page 15 of Applicant's response). Applicant further states, "This method is only disclosed in applicant's specification and therefore even following the Ekins-Daukes I method, one of ordinary skill could not provid [sic] a series of layers which 'exerts substantially no shear force on a neighboring structure'" (see page 15 of Applicant's response).

16. As stated in the prior Office action, these arguments are not persuasive for several reasons. First, Applicant is not claiming a method for making a photovoltaic device, they are claiming the photovoltaic device. Second, Ekins-Daukes clearly teaches, "The *i* region was designed as a 20 period cyclic half-barrier/QW/half-barrier

structure; each half barrier composed of GaAsP alloy, providing half the strain compensation for the InGaAs QW" (see page 4195). Since the strain is zero over each period, each period exhibits substantially zero shear force on its neighboring structures. It is also noted that, although the methods used by Ekins-Daukes et al. may be "insufficiently exact", the device disclosed by Ekins-Daukes et al. is capable of producing MQW photovoltaic devices that exert a "negligible quantity" of strain, which fully satisfies the limitation wherein a period of one tensile strained layer and one compressively strained layer exert "substantially no shear force on a neighboring structure", as recited, for example, in claim 1.

17. While the method to produce the claimed photovoltaic devices may be different than the method used by Ekins-Daukes I, any difference is irrelevant because the instant claims are apparatus claims and Ekins-Daukes I teaches the same apparatus. If Applicant believes the method used to fabricate the photovoltaic devices is an improvement over the methods used by Ekins-Daukes I, as suggested by Dr. Andersons allegation that the Ekins-Daukes I method is "insufficiently exact", then Applicant's should consider the submission of method claims, as opposed to apparatus claims. A reference that discloses a device having the same structure as the structure of the claimed device is not required to provide the same method for fabricating the device.

18. Applicant has also pointed repeatedly to Dr. Anderson's statements regarding the method with which Ekins-Daukes I made their device (see pages 15-16 of Applicant's response). These arguments are not persuasive. First, as explained above, Ekins-

Daukes I disclose that the strain is a negligible quantity, which clearly anticipates claims of substantially no shear force exerted on neighboring structures regardless of the method by which they are made. Second, Dr. Anderson's Declaration states that "the thickness-weighted average lattice constant of wells and barriers is roughly the same as the InP substrate" (see page 5 of the Declaration submitted July 22, 2003). If the lattice constants are "roughly the same", then the period of barriers and quantum wells neighboring the substrate would exert substantially no strain on the substrate. It is noted that the Declaration does not provide actual evidence regarding differences in structure; Dr. Anderson's statements, while respectfully considered, constitute allegations and opinions that do not distinguish the structure of the claimed device from the prior art.

19. Applicant has also argued, "The Examiner has failed to point out where Freundlich I teaches the specific substrate as recited in applicants' claim 18" (see page 18 of Applicant's response). As indicated in rejection of claim 18 in the prior Office action, the buffer layer of Freundlich I is structurally the same as the claimed virtual substrate. As recited on age 4 of the instant disclosure at lines 11-12, the virtual substrate allows lattice matching to a quantum well system having a relatively large lattice constant. In US '310, Freundlich et al. disclose the use of buffer layers "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" (col. 3, lines 58-62). Therefore, the buffer layer is structurally identical to the virtual substrate recited in the instant claims.

20. Regarding the rejection of claims 44-58, Applicant argues, "[T]he Freundlich references do not mention nor recognize the importance of the elastic constants that are set out in the present formulae" (see page 21 of Applicant's response). While the Examiner agrees that Freundlich does not mention or recognize the importance of the elastic constants, it is the Examiner's position that the elastic constants as recited in the instant claims do not structurally distinguish the claimed device from the prior art. The formulae recited in the instant claims are simply the mathematical representations depicting the conditions in which a photovoltaic device is strain-balanced. Since Ekins-Daukes I expressly teaches the desire to have a strain-balanced device, such mathematical limitations are inherent. A strain-balanced device cannot be achieved and not "substantially meet the conditions", as recited in the claim. It is further noted that the scope of "substantially" meeting the conditions set forth by the equations has not been defined in the disclosure. Applicant further states, "[T]he Examiner has cited no reference or citation ... which supports this reasoning" (see page 21 of Applicant's response). According to the MPEP § 2112, "In relying upon the theory of inherency, the examiner must provide a basis in fact and/or technical reasoning to reasonably support the determination that the allegedly inherent characteristic necessarily flows from the teachings of the applied prior art." *Ex parte Levy*, 17 USPQ2d 1461, 1464 (Bd. Pat. App. & Inter. 1990) (emphasis in original). It is the Examiner's position that the required technical reasoning was provided.

21. Since Applicant's arguments are not persuasive, and the prior art teaches all of the structural limitations recited in the instant claims, the rejections are maintained.

Conclusion

22. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

23. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Brian L. Mutschler whose telephone number is (571) 272-1341. The examiner can normally be reached on Monday-Friday from 7:30am to 4:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nam Nguyen can be reached on (571) 272-1342. The fax phone number for the organization where this application or proceeding is assigned is (703) 872-9306.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (703) 308-0661.

NAM NGUYEN
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 1700

blm
January 13, 2004